TESTIMONY/COMMENTS OF CHARLES P. GERBA, Ph.D., RELATED TO DRAFT NPDES PERMIT FOR THE SACRAMENTO REGIONAL WASTEWATER TREATMENT PLANT (SEPTEMBER 3, 2010)

On behalf of the

SACRAMENTO REGIONAL COUNTY SANITATION DISTRICT

I am Charles P. Gerba.

I am employed as a Professor of Environmental Microbiology in the Department of Soil, Water and Environmental Science (College of Agriculture), the Divisions of Environmental Health and Epidemiology) (College of Public Health) at the University of Arizona in Tucson, Arizona since 1981. Previous to that time I was employed as an assistant professor in the Department of Virology and Epidemiology at Baylor College of Medicine in Houston, Texas for seven years. I received my Ph.D. in microbiology from the University of Miami (Florida). I have been involved in field studies on occurrence of pathogenic enteric viruses and protozoa in recreational waters for more than 30 years. Our group conducted the first nationwide studies on the occurrence of *Giardia* and *Cryptosporidium* in surface waters in the United States. I have been involved in studies concerning the application of quantitative microbial risk assessment to assess illness for drinking and recreational waters since 1985. I have written more than 500 published articles concerning environmental transmitted pathogens and their control, including a co-edited book on quantitative microbial risk assessment. I served on the U.S. Environmental Protection Agency Scientific Advisory Board for nine years, which reviews regulations and research programs of the agency. A copy of my resume is attached to this document.

I have performed a quantitative microbial risk assessment to determine the risk of acquiring gastrointestinal illness from the protozoan parasites *Giardia* and *Cryptosporidium* from swimming in the Sacramento River above and below the discharge point of Sacramento Regional County Sanitation District's (SRCSD) Sacramento Regional Wastewater Treatment Plant (SRWTP). I used standard quantitative microbial risk assessment methods, and conservative assumptions on the volume of water ingested, number of recreational events, dilution of the effluent in the river, and efficiency of the analytical methods. Quantitative microbial risk assessment (QMRA) has been used to set guidelines for the treatment of drinking water to control risks from waterborne pathogens by the United States Environmental Protection Agency (USEPA) (Regli et al, 1991). QMRA is a process in which the concentration of pathogens ingested is used to determine the risk of infection and the risk of illness. Risks were calculated for one time exposure event and for 10 swimming exposure events in the Sacramento River. The risks were also combined for both *Giardia* and *Cryptosporidium* representing the maximum risk of gastrointestinal illness from protozoan parasites.

I prepared the preliminary risk assessment report and a revised report titled "Estimated Risk of Illness from Swimming in the Sacramento River" (Estimated Risk Report) which was submitted to the Central Valley Regional Water Quality Control Board (Central Valley Water

Board) in February 2010. The Estimated Risk Report, which was based on a very conservative set of assumptions, contained probabilities of acquiring an illness from *Giardia*, *Cryptosporidium*, and from a combined effect (additive risk from both protozoa) of *Giardia* and *Cryptosporidium* from one and 10 swimming events, which were calculated at four locations on the Sacramento River and for the 20:1 diluted effluent. In no case did the risks exceed those currently recommended by the USEPA for contact recreation. In all cases the risk of illness was below the USEPA acceptable risk value for acquiring an illness or infection for a single event or for multiple events by 2 to 3 orders of magnitude. Furthermore, I found no statistical difference in risks of illness at the sites in the river upstream of the discharge (Veteran's Bridge) and immediately downstream of the SRWTP outfall (Cliff's Marina), even if one adds the risks for both *Giardia* and *Cryptosporidium*. While a minor change in risk is determined 1.5 miles downstream at River Mile 44, those results may be affected by other inputs (e.g. from Morrison Creek and/or the marina).

I have reviewed a letter from the Department of Public Health (DPH) dated 15 June 2010 that references my work. My review has included the appropriateness of a 1:10,000 risk level to regulate the SRCSD discharge, and the comparison of the estimated risks, calculated using conservative assumptions, to the 1:10,000 risk level. In addition, a letter from SRCSD to Mr. Kenneth Landau dated June 30, 2010, relating to the DPH letter describes my analysis and conservative assumptions in the analysis. I agree with the content of the June 30 letter as it relates to microbial risk analysis.

The DPH letter recommended that "additional treatment sufficient to reduce additional risk of infection posed by the exposure to its discharge to as close to 1 in 10,000 as can be achieved by a cost-effective combination of using filtration/and/or a disinfection process that effectively inactivates *Giardia* and *Cryptosporidium* oocysts." The 1:10,000 risk of infection per year is what has been provided by the USEPA as guidance for fully treated tap water (drinking water), not for contact recreational freshwaters. The acceptable national risk for contact recreational surface waters as described in guidance provided by the USEPA is 8:1,000 for a one time exposure. The USEPA 1986 standards apply to all surface recreational waters regardless if they are directly influenced by treated wastewater or not. The USEPA is currently considering revised recreational standards; however, the revisions are not focused on revising the acceptable risk levels. In my experience spanning 33 years, I have not encountered a regulatory agency using a 1:10,000 risk threshold for contact recreation in surface waters.

I have also reviewed the Tentative Permit released by the Central Valley Regional Water Quality Control Board on September 3, 2010. The Tentative Permit states that the Sacramento River near the diffuser is a popular sport fishing area. The Estimated Risk Report reported risk values calculated using an estimate of 100 mL for the amount of water ingested during a swimming event, which is the most conservative estimate of the amounts of water ingested during swimming reported in the scientific literature. By comparison, one study found that a mean of volume 37 mL was ingested by children and a mean volume of 16 mL was ingested by adults during 45 minutes of active swimming (Dufour *et al.*, 2006). The amount of water ingested for boaters and fishing activities (the typical use in the Sacramento River below Freeport) has been estimated as much lower, at 6 to 10 mL (Schets et al, 2008). Therefore, the

reported risk values in the Estimated Risk Report would overestimate the risk of illness from fishing by at least an order of magnitude.

On page F-92, the Tentative Permit states that "at times the risk of illness or infection from pathogenic protozoans nearly quadruples between upstream and downstream of the SRWTP discharge." The Tentative Permit is likely referring to a comparison between the average risk due to *Cryptosporidium* and *Giardia* combined at Veterans Bridge or Freeport with the average risk calculated for 1:20 diluted effluent, which represents a worst-case scenario which is not typically the condition in the Sacramento River. The expected frequency of occurrence of a 20:1 dilution ratio is less than 0.2 percent. Risks that were estimated based on concentrations measured within the river would capture the typical annual variation in effluent dilutions, and more accurately represent conditions downstream of SRWTP discharge. My analysis of the risks of infection to bathers below and above the outfall from *Giardia* and *Cryptosporidium* showed no statistical difference in the risks, indicating that the occurrence of these organisms in the discharge did not result in any substantial increase in risk in the Sacramento River. Furthermore, the risks of illness from protozoa upstream of the discharge and downstream of the discharge both fall well below USEPA criteria for protection of recreational users.

The risks associated with protozoan pathogens from SRWTP discharge likely decrease with distance downstream of the outfall, due to fate and transport process such as die-off from UV light and sedimentation, and also any effect of other water sources that may join the system. Both *Giardia* and *Cryptosporidium* are very sensitive to inactivation by UV light found in sunlight.]

In addition, I have considered the impact of current disinfection processes on *Giardia* viability. In the Estimated Risk Report, I estimated that 24% of the *Giardia* cysts that were detected in the SRCSD discharge were infectious (viable). This value was based on the observed estimated viability of *Cryptosporidium* oocysts reported in the study of Hardwood et al (2005) in secondary treated wastewater. This same percent viability was used for estimating the viability of the *Giardia* cysts detected in the discharge from SRSCD plant, since no data was available on *Giardia* viability in wastewater effluents. The impact of chlorination on the discharge from the plant was not considered in this assessment of *Giardia* viability. *Giardia* is much more susceptible to inactivation by free chlorine and chloramines than *Cryptosporidium* and both of these disinfectants are used by the drinking water industry to control *Giardia* in water supplies (USEPA, 1991). The SRCSD plant chlorinates the effluent from the plant and then dechlorinates before discharge. The time of transport of the chlorinated effluent from the plant to the point of dechlorination allows for time for inactivation of the *Giardia* cysts present in the discharge by the disinfectant. This will result in some inactivation of the *Giardia* by the chloramines in the effluent before discharge.

The effectiveness of chlorine disinfection in the inactivation of *Giardia* cysts is calculated by multiplying the contact time (t) times the concentration of chlorine/chloramines (C) or Ct at a given temperature. The effectiveness of chlorine disinfection increases with increasing temperature. Because of the presence of organic matter and ammonia in the wastewater effluent, the chlorine added to the effluent is quickly converted to chloramines (combined chlorine). The USEPA has provided tables for determining the inactivation of *Giardia* cysts

by chloramines (Table 1) at various temperatures and Ct values. Table 2 shows the temperatures and Ct times for the effluent of the SRCSD plant in 2009. Also, shown in the table are the Ct values for the SRWTP effluent and log reduction expected for *Giardia* viability based on these Ct values. From the Ct times it can be see that the reduction of *Giardia* viability can range from a minimum of 0.84 to greater than 5 $\log_{10}$ with an average of about 3.2 $\log_{10}$. The lowest Ct values were observed for a few days during the winter and the greatest during the summer months. This would suggest that most, if not all, of the *Giardia* detected are non-infectious, except perhaps for a few days during the winter. From this assessment it would appear that when most of the exposure to bathers is likely to occur (spring, summer, and fall) that the risk from *Giardia* is well below 1:10,000/ year.

Table 1. Ct values for inactivation of Giardia Cysts from USEPA (1991)

TABLE E-12

CT VALUES FOR
INACTIVATION OF GIARDIA CYSTS
BY CHLORAMINE pH 6-9(1)

	Temperature (C)					
Inactivation	<=1	5	10	15	20	25
0.5-log	635	365	310	250	185	125
1-log	1,270	735	615	500	370	250
1.5-log	1,900	1,100	930	750	550	375
2-log	2,535	1,470	1,230	1,000	735	500
2.5-log	3,170	1,830	1,540	1,250	915	625
3-log	3,800	2,200	1,850	1,500	1,100	750

Table 2. Calculated $\log_{10}$ reduction for *Giardia* for the SRCSD plant discharge

Range	Temperature °F	Temperature °C	Ct	Log Reduction of *Giardia**
Minimum	57.9	14.9	366	0.84
Average	72.7	22.6	1112	3.2
Maximum	81.3	27.4	2307	>5.0

*Estimated from "Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Water Sources". U. S. Environmental Protection Agency. 1991. Washington, DC.

The risk estimates provided in the Estimated Risk Report were based on conservative assumptions on the viability of *Giardia*. Since *Giardia* cysts are more resistant to disinfection by chlorine/chloramines, the dose and contact time of chloramines at SRWTP can be expected to reduce the level of viable *Giardia* from ~1 to >5 $\log_{10}$. If this is considered in the risk assessment, the risks from *Giardia* are below 1:10,000 for 10 yearly swimming events considering a 1:20 dilution of the discharge. With more realistic assumptions used in the risk assessment and taking the *Giardia* inactivation with chlorine into account, the one in ten thousand risk of illness from *Cryptosporidum* and *Giardia* would likely be achieved.

In summary, I have reached the following conclusions and opinions. Using conservative assumptions, risks of illness from pathogens to persons swimming or otherwise recreating in the Sacramento River downstream of the SRWTP discharge are well below the national USEPA criteria, which are widely used and accepted for protection of public health. In my experience, most rivers in the country could not meet a 1:10,000 risk level, which is used for fully treated drinking water (i.e. tap water) and is considerably more stringent than the USEPA criteria. However, using an analysis with assumptions more realistic than the conservative assumptions in my Estimated Risk Report, the Sacramento River downstream of the SRWTP outfall would definitely approach, and may achieve, such a stringent risk level. Furthermore, the SRWTP discharge does not result in a meaningful increase in risk to recreationists of waterborne disease.

References

Dufour, A.P. et al. 2006. Water ingestion during swimming activities in a pool: a pilot study. J. Water Hlth. 4:425-430.

Regli, S. 1991. Modeling the risk from *Giardia* and viruses in drinking water. J. Am. Water Works Assoc. 84:76-84.

Schets, F.M. et al, 2008. Monitoring of waterborne pathogens in surface waters in Amsterdam, The Netherlands, and the potential health risk associated with exposure to *Cryptosporidium* and *Giardia* in these waters. Appl. Environ. Microbiol. 74:2069-2078.

USEPA. Guidance Manual for Compliance with the Filtration and Disinfection Requirements for Public Water Systems using Surface Water Sources". U. S. Environmental Protection Agency. 1991. Washington, DC.

THE UNIVERSITY OF ARIZONA®

College of Agriculture and Life Sciences

Soil, Water and Environmental Science

swes home

Charles P. Gerba

Professor

Phone: (520) 621-6906

Office: 429 Shantz Building
Tucson, AZ 85721
Fax: (520) 621-1647

Email: gerba@ag.arizona.edu

updated 10/2008

RESEARCH INTERESTS

Quantitative microbial risk assessment, waterborne parasites and viruses, water reuse, development of new disinfectants, domestic microbiology, biocoloid transport in the subsurface

EDUCATION

Ph.D., Microbiology, 1973, University of Miami, Ccoral Gables, FL
B.S., Microbiology, 1969, Arizona State University, Tempe, AZ

POSITIONS

Postdoctoral Fellow, Department of Virology and Epidemiology, Baylor College of Medicine, Houston, Texas 77030 1973

Assistant Professor of Environmental Virology, Department of Virology and Epidemiology, Baylor College of Medicine, Houston, Texas 77030 1974-1981

RESUME

Associate Professor and Professor, Department of Nutrition and Food Science and University Department of Microbiology and Immunology, University of Arizona, Tucson, Arizona 85721 1981-1990

Professor, Department of Soil, Water and Environmental Science, The University of Arizona, Tucson, Arizona 85721, Phone (602) 621-6906 1990-present

Adjunct Professor, Division of Epidemiology and Biostatistics, College of Public Health, The University of Arizona, Tucson, Arizona 85721 2000-present

HONORS

Member of the American Academy of Microbiology

Fellow of the American Society for the Advancement of Science

A. P. Black Award from the American Water Works Association for outstanding contributions to Water Science

Member of the U.S. Environmental Science Agency Science Advisory Board committees on Drinking water Treatment, Research Strategies for nine years.

PUBLICATIONS

BOOKS (10) (Last 10 years)

Haas, C.N., J.B. Rose, and C.P. Gerba. 1999. *Quantitative Microbial Risk Assessment*. John Wiley, NY.

Maier, R.M., I.L. Pepper and C.P. Gerba. 2000. *Environmental Microbiology*. Academic Press, NY.

Pepper, I.L., C.P. Gerba, and J.W. Brendecke. 2004. *Environmental Microbiology - A Laboratory Manual*. Second Edition. Academic Press, San Diego.

Pepper, I. L., C. P. Gerba and M. L. Brusseau. 2006. *Environmental and Pollution Science*, Second Edition. Academic Press, San Diego.

Maier, R.M., I.L. Pepper and C.P. Gerba. 2008. *Environmental Microbiology*. Second Edition. Academic Press, NY.

PEER REVIEWED JOURNAL ARTICLES (304 TOTAL, last 5 years are listed)

Nwachuku, N. and C. P. Gerba. 2004. Health effects of *Acanthamoeba* spp. and its potential for waterborne transmission. Rev. Environ. Contam. Toxicology. 180:93-131.

Karim, M. R., F. D. Manshadi, M. M. Karpiscak, C. P. Gerba. 2004. The persistence and removal of enteric pathogens in constructed wetlands. Water Res. 38:1831-1837.

Brooks, J. P., C. P. Gerba and I. L. Pepper. 2004. Biological aerosol emission fate, and transport from municipal and animal wastes. J. Residuals Sci. Technol.1:16-28.

Tanner, B. J. and C. P. Gerba. 2004. Application of the Ct concept for determining the disinfection of microorganisms in water. J. Swimming Pool Spa Industry 5:8-14.

Chaidez, C. and C. P. Gerba. 2004. Comparison of the microbiological quality of point-of-use (POU)-treated water and tap water. Intl. J. Environ. Hlth. 14:253-260.

Pepper, I. L., P. Rusin, D. R. Quintanar, C. Haney, K. L. Joesphson and C. P. Gerba. 2004. Tracking the concentration of heterotrophic plate count bacteria from the source to the consumer's tap. Intl. J. Food Microbiol. 92:389-295.

Quanrud, D. M., K. Quast, O. Conroy, M. M. Karpiscak, C. P. Gerba, K. E. Lansey, W. P. Ela and R. G. Arnold. 2004. Estrogenic activity and volume fraction of waste water origin in monitoring wells along the Santa Cruz River, Arizona. Ground Water Monitoring and Remediation. 24:86-93.

Nwachuku, N. and C. P. Gerba. 2004. Microbial risk assessment: don't forget the children. Curr. Opinion Microbiol. 7:1-4.

Nwachuku, N. and C. P. Gerba. 2004. Emerging waterborne pathogens: can we kill them all? Curr. Opinion Biotechnol. 15:175-180.

Pantoja, C. R., S. A. Navarro, J. Naranjo, D. V. Lightner and C. P. Gerba. 2004. Nonsusceptibility of primate cells to taura syndrome virus. Emerg. Infect. Dis. 10:2106-2112.

Choi, C., I. Song, S. Stine, J. Pimental and C. Gerba. 2004. Role of irrigation reuse:comparision of subsurface irrigation and furrow irrigation. Water Sci. Technol. 50:61-68.

Tanner, B. D., S. Kuwahara, C. P. Gerba and K. A. Reynolds. 2004. Evaluation of electrochemically generated ozone for the disinfection of water and wastewater. Water Sci. Technol. 50:19-25.

Brooks, J. P., B. D. Tanner, K. L. Joesphson, C. P. Gerba and I. L. Pepper. 2004. Bioaerosols from the land application of biosolids in the desert southwest USA. Water Sci. Technol. 50:7-12.

Reynolds, K. A., P. M. Watt, S. A. Boone and C. P. Gerba. 2005. Occurrence of bacteria and biochemical markers on public surfaces public surfaces. Intl. J. Environ. Hlth. Res. 15:225-234.

Song, I., C. Y. Choi, S. O'Shaughnessy and C. P. Gerba. 2005. Effects of temperature and moisture on coliphage PRD-1 survival in soil. J. Food Protect. 68:2118-2122.

Haas, C. N., J. R. Marie, J. B. Rose and C. P. Gerba. Assessment of benefits from use of antimicrobial hand products: reduction in risk from handling ground beef. Int. J. Hyg. Environ. Hlth. 208:461-466.

Boone, S. A. and C. P. Gerba. 2005. The occurrence of influenza A virus on household and day care center fomites. J. Infect. 51:102-109.

Nwachuku, N. C. P. Gerba, A. Oswald and F. D. Mashadi. 2005. Comparative inactivation of adenovirus serotypes by UV light disinfection. Appl. Environ. Microbiol. 71:5633-5636.

Thurston-Enriquez, J. A., C. N. Haas, J. Jacangelo and C. P. Gerba. 2005. Inactivation of enteric adenovirus and feline calicivirus by ozone. Water Res. 39:3650-3666.

Stine, S. W., I. Song, C. Y. Choi and C. P. Gerba. 2005. Application of microbial risk assessment to the development of standards for enteric pathogens in water used to irrigate fresh produce. J. Food Protect. 68:913-918.

Brusseau, M. L., J. K. Oleen, J. Santamaria, L. Cheng, P. Orosz-Coghlan, A. S. Chetochine, W. J. Blanford, P. Rykwalder and C. P. Gerba. 2005. Transport of microsporidium *Encephalitozoon intestinales* spores in sandy loam porous media. Water Res. 39:3636-3642.

John, D. E., C. N. Haas, N. Nwachuku and C. P. Gerba .2005. Chlorine and ozone disinfection of *Encephalitozoon intestinalis* spores. Water Res. 39:2369-2375.

Blanford, W. J., M. L. Brusseau, T. C. J. Yeh, C. P. Gerba and R. Harvey. 2005. Influence of water chemistry and travel distance on bacteriophage PRD-1 transport in a sandy aquifer. Water Res. 39:2345-2357.

Thurston-Enriquez, J. A., C. N. Haas, J. Jacangelo and C. P. Gerba. 2005. Inactivation of enteric adenovirus and feline calicivirus by chlorine dioxide. Appl. Environ. Microbiol. 71:3100-3105.

Zaleski, K. J., K. L. Josephson, C. P. Gerba and I. L. Pepper. 2005. Potential regrowth and recolonization of salmonellae and indicators in biosolids and biosolid-amended soil. Appl. Environ. Microbiol. 71:3701-3708.

Brooks, J. P., B. D. Tanner, K. L. Josephson, C. P. Gerba, C. N. Haas and I. L. Pepper. 2005 A national study on the residential impact of biological aerosols from the land application of biosolids. J. Appl. Microbiol. 99:310-322.

Stine, S. W., I. Song, C. Y. Choi and C. P. Gerba. 2005. The effect of relative humidity on preharvest survival of bacterial and viral pathogens on the surface of cantaloupe, lettuce, and bell peepers. J. Food Protect. 68:1352-1358.

Gerba, C. P. and J. E. Smith. 2005. Sources of pathogenic microorganisms and their fate during land application of wastes. J. Environ. Qual. 34: 42-48.

Zaleski, K. J., K. L. Josephson, C. P. Gerba and I. L. Pepper. 2005. Survival, growth and regrowth of enteric indicator and pathogenic bacteria in biosolids, compost, soil, and land applied biosolids. J. Rediduals Sci. Technol. 2:49-63.

Orosz-Coghlan, P. A., P. A. Rusin, M. M. Karpiscak and C. P. Gerba. 2006. Microbial source tracking of *Escherichia coli* in a constructed wetland. Res. J. Water Environ. Assoc. 78:227-232.

Chetochine, A. S., M. L. Brusseau, C. P. Gerba and I. L. Pepper. 2006. Leaching of phage from class B biosolids and potential transport through soil. Appl. Environ. Microbiol. 72:665-671.

Brooks, J. P., B. D. Tanner, C. P. Gerba and I. L. Pepper. 2006. The measurement of aerosolized endotoxin from land application of class B biosolids in southeastern Arizona. Can. J. Microbiol. 52:150-156.

Song, I., S. W. Scott, C. Y. Choi and C. P. Gerba. 2006. Comparison of crop contamination by microorganisms during subsurface drip and furrow irrigation. J. Environ. Eng., 132:1243-1248.

Yepiz-Gomez, M. S., K. R. Bright and C. P. Gerba. 2006. Bacterial occurrence on tabletops and in dishcloths used to wipe down tabletops in public restaurants and bars. Food Protect. Trends, 26:24-30

Al-Hmoud, N., S. A. O'Shaughnessy, W. Sulleiman, C. P. Gerba and C. Y. Choi.2006. Disinfection of bacterial pathogens and indicators in biosolids in Jordan. J. Residuals Sci. Technol. 3:185-191.

Pepper, I. L., J. P. Brooks and C. P. Gerba. 2006. Pathogens in biosolids. Adv. Agronomy, 90:1-40.

Nwachuku, N. and C. P. Gerba. 2006. Health risks in children. Rev. Environ. Contam. Toxicol. 186:1-56.

Vidales-Contreras, C. P. Gerba, M. M. Karpoiscark, K. Acuna-Askar and C. Chaidez-Quiroz. 2006. Transport of coliphage PRD1 in a surface flow constructed wetland. Water Environ. Res. 78:2253-2260.

Straub TM, K. Höner zu Bentrup, P. O. Orosz-Coghlan, A. Dohnalkova, B. K. Mayer, R. A. Bartholomew, C. O. Valdez, C. J. Bruckner-Lea, C. P. Gerba, M. Abbaszadgen and C. A. Nickerson. 2007. In vitro cell culture infectivity assay for human noroviruses. Emerg Infect Dis. 13:396-403.

Jones, E. L. A. Kramer, M. Gaither and C. P. Gerba. 2007. The role of fomite contamination during an outbreak of norovirus on houseboats. Intl. J. Environ. Hlth. 17:1-9.

Del Campo, N. C., I. L. Pepper and C. P. Gerba. 2007. Assessment of *Salmonella* growth in Class A biosolid mixtures. J. Resid. Sci Technol. 4:83-88.

Boone, A. A. and C. P. Gerba. 2007. Significance of fomites in the spread of respiratory disease and enteric viral disease. Appl. Environ. Microbiol. 73:1687-1696.

Brooks, J. P., S. L. Maxwell, C. Rensing C. P. Gerba and I. L. Pepper. 2007. Occurrence of antibiotic resistant bacteria and endotoxin associated with land application of biosolids. Canad. J. Microbiol. 53:616-622.

Gerba, C. P. and D. Kennedy. 2007. Enteric virus survival during household laundering and impact of disinfection with sodium hypochlorite. Appl. Environ. Microbiol. 73:4425-4428.

Brooks, J. P., C. P. Gerba and I. L. Pepper. 2007. Diversity of aerosolized bacteria during land application of biosolids. J. Appl. Microbiol. 10:1779-1790.

Silvestry-Rodriguez, N., K. R. Bright, D. R. Uhlmann, D. C. Slack and C. P. Gerba. 2007. Inactivation of *Pseudommonas aeruginosa* and *Aeromonoas hydrophila* by silver in water. J. Envion. Sci. Hlth. Part
A. 42: 1579-1584.

Silvestry-Rodriguez, N., K. E. E. Sicairos-Ruelas, C. P. Gerba and K.R. Bright. 2007. Silver as a disinfectant. Rev. Environ. Contam. Toxicol. 191:23-45.

Reynolds, K A., K. D. Mena and C. P. Gerba. 2008. Risk of waterborne illness via drinking water in the United States. Rev. Environ. Contam. Toxicol. 192:117-158.

Sinclair, R., S. A. Boone, D. Greenberg, P. Keim, and C. P. Gerba. 2008. Persistence of Category A select agents in the environment. Appl. Environ. Microbiol. 74:555-563.

Silvestry-Rodriguez, N., K. R. Bright, D. C. Slack, D. R. Uhlmann, and C. P. Gerba. 2008. Silver as a residual disinfectant to prevent biofilm formation in water distribution systems. Appl. Environ. Microbiol., 74:1639-1641.

Kim, M., C. Y. Choi, and C. P. Gerba. 2008. Source tracking of microbial intrusion in water systems using artificial neural networks. Water Res., 42:1308-1314.

Karim, M. R., E. P. Glenn and C. P. Gerba. 2008. The effect of wetland vegetation on the survival of *Escherichia coli*, *Salmonella typhimurium*, bacteriophage MS-2 and polio virus. J. Water Hlth. 6:167-175.

Gerba, C. P., J. E. Naranjo and E. L. Jones. 2008. Virus removal from water by a portable treatment device. Wilderness Environ. Med., 19:45-49.

Rodriquez, R. A., P. M. Gundy and C. P. Gerba. 2008. Comparison of BGM and PLC/PRC/5 cell lines for total culturable viral assay of treated sewage. Appl. Environ. Microbiol. 74:2583-2587.

Nwachuku, N. and C. P. Gerba. 2008. Occurrence and persistence of *Escherichia coli* 0157:H7. Rev. Environ. Sci. Biotechnol., 7:267-273.

Tanner, B. D., Brooks, J. P., Gerba, C. P, C. N. Haas, K. L. Josephson and I. L. Pepper. 2008. Estimated occupational risk from biosolids generated during land application of class B biosolids. J. Environ. Qual. 37:in press.

Gerba, C. P., Castro-del Campo, J. P. Brooks and I. L. Pepper. 2008. Exposure and risk assessment of Salmonella in recycled residuals. Water Sci. Technol. 57:1061-1065.

Pepper, I. L., H. Zerzghi, J. P. Brooks and C. P. Gerba. 2008. Sustainability of land application of class B biosolids. J. Environ. Qual. 37:in press.

Blair, B., P. Dakar, K. R. Bright, F. Marciano-Cabral, and C. P. Gerba. Naeglaria fowleri in well water. Emerg. Infect. Dis. 14:1499-1500.

BOOK CHAPTERS (76) (last 5 years)

Gerba, C. P. 2004. Risk assessment and environmental regulations. In: Environmental Monitoring and Remediation, J. Artiola, I. L. Pepper and M. Brusseau, eds. pp. 377-392. Academic Press, San Diego.

Gerba, C. P. and I. L. Pepper. 2004. Microbial contaminates. In: Environmental Monitoring and Remediation, J. Artiola, I. L. Pepper and M. Brusseau, eds. pp. 313-333. Academic Press, San Diego.

Gerba, C. P., C. Rensing and C. P. Gerba. 2004. Microbiological properties and processes. In: Environmental Monitoring and Remediation, J. Artiola, I. L. Pepper and M. Brusseau, eds. pp. 263-280. Academic Press, San Diego.

Mena, K. D., J. B. Rose and C. P. Gerba. 2004 Addressing microbial food safety issues quantitatively: a risk assessment approach. In: Preharvest and Postharvest Food Safety. R. C. Beier, S. D. Pillai, T. D. Phillips and R. L. Ziprin., eds. Blackwell. Ames IA.

Gerba, C. P. 2005. Pathogens. In: Encyclopedia of Hydrological Sciences. M. G. Anderson, ed. Chapter 98, pp. 981-911 Wiley, NY.

Gerba, C. P. Survival of viruses in the marine environment. In: Oceans and Health: Pathogens in the Marine Environment. S. Belkin and R. Colwell, eds. pp. 133-141. Springer, NY.

Gerba, C. P. 2005. Enteric viruses in biosolids. Infectious Disease Agents in Sewage Sludge and Manure. J. E. Smith, P. D. Millner, W. Jakubowski, N. Goldstein and R. Rynk., eds. pp. 93-99. JG Press. Emmaus, PA.

Gerba, C. P. 2006. Food Virology: Past, Present and Future. In: Viruses in Foods. S. M. Goyal, Ed. pp. 1-4.
Springer, NY.

Gerba, C. P. and C. Y. Choi. 2006. Role of irrigation in crop contamination by viruses. In: Viruses in Foods. S. M. Goyal, ed. pp. 257-263.

Pepper, I. L., C. P. Gerba and M. L. Brusseau. 2006. The extent of global pollution. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 3-12. Academic Press, San Diego.

Gerba, C. P. and I. L. Pepper. 2006. Microbial contaminants. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 144-169 Academic Press, San Diego.

Gerba, C. P. 2006. Toxicology. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 183-211. Academic Press, San Diego.

Gerba, C. P. 2006. Risk Assessment. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 212-232. Academic Press, San Diego.

Gerba, C. P. and C. Straub. 2006. Environmental law and regulations. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 233-240. Academic Press, San Diego.

Gerba, C. P. 2006. Municipal wastewater treatment. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 429-450. Academic Press, San Diego.

Gerba, C. P. and I. L. Pepper. 2006. Land application of biosolids and animal wastes. In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 451-467. Academic Press, San Diego.

Pepper, I. L., C. P. Gerba and M. L. Brusseau. 2006. Epilogue: Is the future of pollution history? In: Environmental and Pollution Science, 2nd ed. I. L. Pepper, C. P. Gerba and M. L. Brusseau, eds. pp. 516-520. Academic Press, San Diego.

Gerba, C. P. 2006. Hepatitis E virus. In: Waterborne Pathogens, 2nd ed. Pp.279-280. American Water Works Association. Denver, CO.

Gerba, C. P. 2006. Enteroviruses and parechoviruses. In: Waterborne Pathogens, 2nd ed. Pp. 267-271. American Water Works Association. Denver, CO.

Gerba, C. P. 2006. Emerging viruses. In: Waterborne Pathogens, 2nd ed. Pp. 263-265. American Water Works Association. Denver, CO.

Gerba, C. P. 2006. Bacteriophage as pollution indicators. In: The Bacteriophages, 2nd ed. R. Calendar, ed. pp.695-701. Oxford University Press, Oxford, UK.

Gerba, C. P. 2007. Virus occurrence and survival in the environmental waters. In: Human Viruses in Water. A. Bosch, ed. pp. 91-108. Elsevier, Amsterdam.

Gerba, C. P. and C. A. Scott. 2008. Animal and human waste as vehicles for cross-contamination of imported foods. In: Microbiological Issues and Challenges. M. P. Doyle and M. C. Erickson. pp.113-138. ASM Press, Washington, DC.